Bone Density Following Three Years of Recovery from Long-Duration Space Flight

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BACKGROUND

- It is well recognized that bone mineral density [BMD] at load-bearing sites of the hip and spine sustain significant loss during space flight, estimated at ~0.5-1.0% per month. (LeBlanc J Musc Neur Int 2007)
- However, the long-term effects on bone health following return from long-duration space flight remain unclear.
- Using prediction models for BMD created from community adults (which included the age range of US astronauts), we have previously shown that at ~12 months following return from a long-duration mission in space, men, but not women, had lower BMD at most sites than would be predicted had they not been exposed to microgravity. (Amin [abstract] 2010)
- It is unknown whether BMD for men recovers beyond 1 year following return from space to what would be predicted or if deficits persist.

OBJECTIVE

- Using our previously created prediction models, we compared the observed BMD of male US crew following 3 years since returning from long-duration space flight with what would be predicted if they had not been exposed to microgravity.

METHODS

Study Subjects

- Male US crew members serving on long-duration missions in space aboard Mir or ISS who had BMD measurements beyond ~12 months since their return.
- Of 36 US crew who have served on Mir or ISS, and have had pre- and at least one post-flight BMD measured as of December 2010, 28 are men.
- 15/28 men [mean age ± SD at pre-flight BMD: 47 ± 5 yrs, range: 36-54 yrs] have had their BMD measured up to ~3 yrs after landing.

METHODS

Prediction Models for BMD

- Prediction models were created using 348 men [mean age ± SD: 55 ± 20 yrs, range: 22-90 yrs] who represented an age-stratified random sample of the Rochester, MN community, and who have had longitudinal BMD measurements over 4 yrs of follow-up.

BMD Measurements in US Crew members

- BMD (g/cm^2) was measured in US crew members pre-flight, immediately post-flight and ~36 months post-flight
- BMD from US crew members were measured using DXA (Hologic QDR 2000, QDR 45000 and Discovery scanners), with at least half having pre- and post-flight measurements on the same machine.
- BMD measures at the total hip, lumbar spine, wrist (ultra-distal and mid-shaft radius) and total body were used in analyses.

BMD Measurements in Community-Based Cohort

- BMD was measured in the community-based cohort of men at baseline, 2 yrs and 4 yrs of follow-up using the QDR 2000 scanner and at the same sites listed for US crew members.

Analyses

- We created prediction models for follow-up BMD using the community cohort of men.
- We used linear mixed-effects models to predict follow-up BMD using baseline BMD, age and follow-up time, adjusting for the fact that most people were measured more than once.
- We then applied the created models to predict follow-up BMD for US crew members and compared them to what was actually observed immediately and at ~36 months post-flight

RESULTS

- Median flight duration was 179 days (range 115-215 days) for the 15 male US crew.
- The immediate post-flight BMD was measured a median of 19 days (range: 3-33 days) after their landing.
- BMD was also measured a median of 36 months after landing (range 33-41 months), and none of the 15 male US crew had had a second long-duration mission in space in the interim.

RESULTS

BMD Site*	Mean Immediate Post-Flight BMD [g/cm^2] % Change per Month (95% Confidence Interval)					
		Predicted		Observed		
	Pre-Flight BMD	BMD	% change/month (95% CI)	BMD	% change/month (95% CI)	p-value**
Total Hip	1.079	1.082	0.04 (0.00, 0.07)	1.007	-0.79 (-1.00, -0.58)	<0.001
Lumbar Spine	1.082	1.092	0.11 (0.09, 0.13)	1.024	-0.60 (-0.82, -0.38)	<0.001
Ultra-Distal Radius	0.555	0.552	-0.05 (-0.06, -0.04)	0.544	-0.21 (-0.41, -0.00)	<0.01
Mid Shaft Radius	0.738	0.751	0.18 (0.13, 0.24)	0.735	-0.03 (-0.18, 0.11)	0.02
Total Body	1.299	1.294	-0.04 (-0.05, -0.03)	1.262	-0.31 (-0.46, -0.15)	0.03

* N=14 for the hip and N=10 for the radius sites

**p-value for difference between predicted vs. observed BMD

BMD Site*	Mean 3 Year Post-Flight BMD [g/cm^2] % Change per Month (95% Confidence Interval)					
		Predicted		Observed		
	Pre-Flight BMD	BMD	% change/month (95% CI)	BMD	% change/month (95% CI)	p-value**
Total Hip	1.079	1.085	0.01 (0.01, 0.02)	1.063	-0.03 (-0.05, -0.01)	<0.001
Lumbar Spine	1.082	1.096	0.03 (0.03, 0.03)	1.081	-0.00 (-0.04, 0.03)	0.10
Ultra-Distal Radius	0.555	0.535	-0.08 (-0.09, -0.07)	0.546	-0.04 (-0.06, -0.01)	<0.01
Mid Shaft Radius	0.738	0.745	0.02 (0.00, 0.03)	0.736	-0.00 (-0.05, 0.04)	0.18
Total Body	1.299	1.291	-0.01 (-0.02, -0.01)	1.271	-0.04 (-0.10, 0.01)	0.23

* N=14 for the hip and N=10 for the radius sites

**p-value for difference between predicted vs. observed BMD

SUMMARY OF RESULTS

- Among the 15 male US crew who have had BMD measured at least ~3 yrs after landing, only BMD at the hip continues to be lower than would be predicted.

LIMITATIONS

- BMD is a surrogate measure of bone strength; differences in predicted and observed BMD may still underestimate deficits in bone strength, given recent findings based on finite-element models of QCT hip scans from US crew (Lang JBMR 2004 & 2006; Keyak Bone 2009).
- There were too few women with BMD measures ~3 yrs after landing to be able to confirm that there remained no long-term negative effects on bone.
- Analyses are limited to those men who returned for BMD measures.

CONCLUSIONS

- By ~3 yrs after landing, BMD at most sites in male US crew became closer to what would be predicted, derived from a community-based cohort of men.
- However, hip BMD, the site most affected by exposure to microgravity, remained lower than what would be predicted, even after ~3 yrs following return from space.
- Findings suggest a potential long-term negative impact of long-duration space flight on load-bearing bones of men.
- Implications of these findings on future hip fracture risk for men serving on long-duration missions in space remain unknown.

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